NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

DEVELOPMENT OF A MARKOV MODEL FOR FORECASTING CONTINUATION RATES FOR ENLISTED PRIOR SERVICE AND NON-PRIOR SERVICE PERSONNEL IN THE SELECTIVE MARINE CORPS RESERVE (SMCR)

by

Bruce J. Erhardt Jr.

March 2012

Thesis Advisor: Chad W. Seagren
Second Reader: Benjamin J. Roberts

Approved for public release; distribution is unlimited

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE		*Form Approved OMB No. 0704-0188*

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE March 2012	3. REPORT TYPE AND DATES COVERED Master's Thesis
4. TITLE AND SUBTITLE Development of a Markov Model for Forecasting Continuation Rates for Enlisted Prior Service and Non-Prior Service Personnel in the Selective Marine Corps Reserve (SMCR)		**5. FUNDING NUMBERS**
6. AUTHOR(S) Bruce J. Erhardt Jr		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000		**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A		**10. SPONSORING/MONITORING AGENCY REPORT NUMBER**

11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government. IRB Protocol number _____N/A_____.

12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited	12b. DISTRIBUTION CODE A

13. ABSTRACT (maximum 200 words)
The purpose of this thesis is to develop a Markov model to determine the continuation rates for Prior Service and Non-Prior Service enlisted population in the Selected Marine Corps Reserve (SMCR). Determining the end strength for these populations is necessary for reserve manpower planners to balance the force structure to minimize personnel overage or underages that impact training and labor costs, as well as career progression. The results of model validation indicate that models based on annual aggregate monthly transition rates fails the stationarity assumption required of Markov models. These results suggest that the attrition behaviors are seasonal for both enlisted populations leading to numerous states being non stationary in part due to their correlation with seasonality. We recommend developing and employing models with unique transition rates for each month.

14. SUBJECT TERMS Manpower Planning, Markov Model	15. NUMBER OF PAGES 65
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UU

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

i

THIS PAGE INTENTIONALLY LEFT BLANK

DEVELOPMENT OF A MARKOV MODEL FOR FORECASTING CONTINUATION RATES FOR ENLISTED PRIOR SERVICE AND NON-PRIOR SERVICE PERSONNEL IN THE SELECTIVE MARINE CORPS RESERVE (SMCR)

Bruce J. Erhardt Jr
Major, United States Marine Corps
B.A., University of Florida, 1994
M.A., University of Florida, 1995

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

**NAVAL POSTGRADUATE SCHOOL
March 2012**

Author: Bruce J. Erhardt Jr

Approved by: Chad W. Seagren
                 Thesis Advisor

                 Benjamin J. Roberts
                 Second Reader

                 Bill Gates
                 Dean, Department of Graduate School of Business and Public
                 Policy

iii

THIS PAGE INTENTIONALLY LEFT BLANK

ABSTRACT

The purpose of this thesis is to develop a Markov model to determine the continuation rates for Prior Service and Non-Prior Service enlisted population in the Selected Marine Corps Reserve (SMCR). Determining the end strength for these populations is necessary for reserve manpower planners to balance the force structure to minimize personnel overage or underages that impact training and labor costs, as well as career progression. The results of model validation indicate that models based on annual aggregate monthly transition rates fail the stationarity assumption required of Markov models. These results suggest that the attrition behaviors are seasonal for both enlisted populations leading to numerous states being nonstationary in part due to their correlation with seasonality. We recommend developing and employing models with unique transition rates for each month.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

LIST OF FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

MARINE CORPS RESERVE COMPCODES

Code	Description
2O	PLC, NROTC OR RESERVE OFFICER CANDIDATE
A1	FMCR
A8	USMCR RETIRED, (NON PAY)
A9	USMCR RETIRED, (PAY) ENLISTED
AH	USMCR, RETIRED HONORARY
AR	USMC RET
B1	RES OFF/ENL ORDERED TO ACTIVE DUTY TO PROVIDE FTS
B2	FTS RES RECRUITING
B3	FTS RES INSTR/TRNG
B4	FTS RES ORGANIZATION
B5	SMCR ENLISTED IDT,NONPRIOR ON IADT/AWAIT IADT (WITH PAY)
CB	RES MANDATORY PARTICIPANT FOR MORE THAN 45 DAYS
CJ	PLC LAWYER
K1	ENLISTED RES ON IADT AND/OR ELST
K4	ENLISTED RES NPS OBLIGOR 6 YR ACDU & IDT
K5	ENL REGULAR USMC CONTRACTED AND AWAITING SHIPMENT IN THE DEP
K6	FTS, POLICY & REGULATIONS
K7	IRR, MTU RU 88900-88906, IRR MBR IN OFFICER TRNG PGM
K8	ENL RESERVE, NPS, OBLIGOR, 3YR ACDU & IDT
K9	SMCR ENLISTED IDT,NONPRIOR ON IADT/AWAIT IADT (WITH PAY)
KA	SMCR IDT
KD	STANDBY RESERVE AND KEY FEDERAL OFF, INACT LIST, ACT STAT
KE	STANDBY RESERVE INACTIVE LIST
KF	IMA IDT
KG	IRR ASSIGNED AS A MOBILIZATION DESIGNEE
KP	PLC;ENLISTED PARTICIPANT IN OFFICER COMMISSIONING PROGRAM

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF ACRONYMS AND ABBREVIATIONS

AC	Active Component
ADT	Active Duty for Training
AR	Active Reserve
ASL	Active Status List
ASR	Authorized Strength Report
AT	Annual Training
DC M&RA	Deputy Commandant for Manpower and Reserve Affairs
DoD	Department of Defense
FMCR	Fleet Marine Corps Reserve
FY	Fiscal Year
HQMC	Headquarters Marine Corps
IADT	Initial Active Duty for Training
IDT	Inactive Duty Training
IMA	Individual Mobilization Augment
IRR	Individual Ready Reserve
ISL	Inactive Status List
M&RA	Manpower and Reserve Affairs
MARADMIN	Marine Administrative Message
MARFORRES	Marine Forces Reserve
MCMPS	Marine Corps Mobilization Processing System
MCO	Marine Corps Order
MCRAMM	Marine Corps Reserve Administrative Management Manual
MCRC	Marine Corps Recruiting Command
MCTFS	Marine Corps Total Force System
MOBCOM	Mobilization Command
MOS	Military Occupational Specialty
MSO	Military Service Obligation
NDAA	National Defense Authorization Act
NPS	Non-Prior Service
PMOS	Primary Military Occupational Specialty
PS	Prior Service

RA	Reserve Affairs
RAP	Reserve Affairs Personnel Plans and Policy
RASL	Reserve Active Status List
RC	Reserve Component
RCT	Reserve Counterpart Training
RDOL	Reserve Duty On-Line
SecDef	Secretary of Defense
SECNAV	Secretary of the Navy
SELRES	Selected Reserve
SMCR	Selected Marine Corps Reserve (Units)
TECOM	Training and Education Command
T/O	Table of Organization
TFDW	Total Force Data Warehouse
TFSMS	Total Force Structure Management System
UCMJ	Uniform Code of Military Justice
USMC	United States Marine Corps

ACKNOWLEDGMENTS

First and foremost, I want to thank my wife, Robyn, for all the sacrifices she endured throughout this process and for helping me stay focused. I love her and owe her more than I can ever repay. I also want to thank my children, Leah, Cora, and Collin, who without knowing it provide the inspiration to complete this process.

Major Chad Seagren, without your guidance and commitment this thesis would have never been completed. The time and patience you allotted me paved the way for this major goal to be accomplished. Your dedication, insight and constant mentoring throughout the entire thesis process were much appreciated.

I would also like to thank my co-advisor, Benjamin J. Roberts, for accepting this challenge and providing valuable insight throughout this process.

I am also grateful to the efforts of LtCol Price and Capt Nick Pergar, whose willingness to answer random e-mails, phone calls, and request for STATA data manipulation assistance throughout this process was critical.

THIS PAGE INTENTIONALLY LEFT BLANK

I. INTRODUCTION

A. PURPOSE

The purpose of this thesis is to analyze the continuation rates and predictive models for Selected Marine Corps Reserve (SMCR) enlisted Marine end strength in the non-prior service and prior service populations and to develop and validate a Markov model to forecast SMCR end strength more accurately beyond the current fiscal year (FY). The primary purpose for this thesis is the following.

- Construct a Markov model that accurately estimates future FY inventories of non-prior service (NPS) SMCR Marines.

- Construct a Markov model that accurately estimates future FY inventories of prior service SMCR Marines.

B. BACKGROUND

In response to the Department of Defense's (DoD) total force policy, the reserve component was designed to have the same capabilities exhibited in the active force, and to provide the means for rapid augmentation and expansion of the Marine Corps during a national emergency. The ability to augment the active force seamlessly is the dominant theme of total force planning, training, and administration. During this decade, the Marine Corps Reserve has transformed from a strategic to an operational reserve.

> The transition in utilization of the Marine Corps Reserve from a strategic to operational Reserve, as affirmed by the Marine Corps' recent force structure review, expands the Corps 'ability to perform as America's Expeditionary Force in Readiness.'[1]

The shift from a strategic to operational reserve dictates the effective management of the reserve enlisted personnel inventory to ensure that the Marine Corps Reserve continues to be an operational force multiplier for the Marine Corps.

Recent events have affected the rates at which the Marine Corps Reserve recruits and retains NPS and prior service (PS) enlisted populations. As these rates fluctuate, it

---

[1] Statement of Commandant of the Marine Corps General Amos to the House Armed Services Committee in 2011 outlining the importance of the Marine Corps Reserve continued focus the operational rather than the strategic level of war.

becomes difficult for manpower planners to forecast recruiting and retention requirements. Reserve Manpower Planner's ability to forecast end strength of reserve enlisted populations accurately has historically been difficult due to the uncertainty associated with their environment. The nature of the current reserve manpower model makes obtaining the statutory end strength a complicated task.

The current manpower model that Reserve Affairs Personnel Plans (RAP-2) utilizes is a moving average model that the reserve manpower planner updates on a monthly basis. The data produced is entered into the model that provides a forecast of SMCR enlisted end strength for the end of the current FY. This current model provides RAP-2 with accurate monthly end strength numbers but limits their ability to forecast future FY end strengths. This restriction deprives them of the ability to war game different accession schedules as stated in the Reserve Component Accession and Retention Plan (PS Memo 01) to allow them to obtain but not exceed their authorized end strength. The Marine Corps is assigned their mandated end strength by the National Defense Authorization Act (NDAA).

1.   National Defense Authorization Act

The NDAA is the annual legislative law that authorizes funding for the DoD. The NDAA § 411 provides end strength authorization to the Armed Forces, and since FY04, the total reserve manpower end strength for the Marine Corps Reserve has stayed constant at 36,900.

2.   U.S. Code Authorization

The U.S. Code Authorization provides further guidance to the armed forces regarding requirements for annual authorization of personnel end strength. The 10 U.S.C. § 115 states that each service must submit a waiver to request authorization to increase end strength for a given fiscal year and must not exceed 3% above the authorized end strength numbers.[2] It stipulates that the Marine Corps must request a waiver from the Secretary of the Navy (SecNav) for any increase equal to but not more than 2% of

---

[2] S Personnel strengths requirements are detailed in U.S. Code 10, §115.

authorized end strength.[3] For any increase equal to but not more than 3% of authorized end strength, the Marine Corps must request authorization from the Secretary of Defense (SecDef).[4] This increase is the only tolerance allowed regarding end strength numbers. No authorized number exists for falling under authorized end strength.

3.   Reserve Component Accession and Retention Plan (PS Memo 01)

The ability to forecast annual end strengths accurately allows RAP the opportunity to adjust its monthly accessions requirements that it submit to Marine Corps Recruiting Command (MCRC) to recruit and ship to Marine Corps Recruit Depots (MRCD). On an annual basis, the Marine Corps must recruit approximately 5,700 new enlistees per year into its reserve component. An accurate forecast is paramount to generate the appropriate numbers, types, and qualities of individuals required by the Marine Corps to support current and future operations.

RAP-2 publishes the PS Memo 01 annually to provide MCRC their accession mission for each FY. The PS Memo 01 informs MARFORRES its retention and attrition goal for the current FY and its mission for future FYs. RAP-2 uses PS Memo 01 as a template to guide its accessions goals to MCRC and Training and Education Command (TECOM) so they can program the essential recruiting and training requirements to ensure that units within the Reserve Component will have the necessary personnel to accomplish their mission. Therefore, it is critical that predictions be as precise as possible to be within the legislative end strength mandates.

The Markov model developed in this thesis accurately forecasts accession requirements, attrition, and available manpower assets to shape the reserve their force structure. The advantage that a Markov model has over the current moving average model is that it permits RAP-2 to analyze personnel policies more efficiently and with more accuracy, which allows them to forecast end strength impacts in the current and future budgetary constraint environment, and to communicate recruiting and retention missions to MCRC and Marine Forces Reserve (MARFORRES). Utilizing a Markov

---

[3] S Personnel strengths requirements are detailed in U.S. Code 10, §115.

[4] Ibid.

model affords RAP-2 the ability to forecast annual end strengths accurately, which enhances the probability of attaining the authorized end strength mandated in the NDAA.

C.   SCOPE AND METHODOLOGY

The goal of this thesis is to develop a Markov model to assist RAP-2 at Headquarters Marine Corps (HQMC) in the accurate forecast of future FY inventories of NPS and PS SMCR Marines. Currently, no model exists that can provide an accurate projection for NPS and PS enlisted populations to sustain the desired end strength structure for the long run. The data used for this research was acquired from the Total Force Data Warehouse (TFDW) and includes all reserve enlisted personnel accessions and losses from the period of 31 October 06 to 30 September 11.

D.   ORGANIZATION OF STUDY

Chapter II is a broad overview of the Marine Corps Reserve organization and structure with an emphasis on the Select Reserves. Chapter III presents a short literature review of Markov model basic theoretical framework and previous research on Marine Corps Reserve manpower issues. Chapter IV presents the data and methodology. Chapter V presents the model implementation and validation for this study. Chapter VI contains the conclusions and recommendations from this research study.

II. RESERVE ORGANIZATION AND STRUCTURE

A. INTRODUCTION

The mission of the reserve component of the Marine Corps as stated in the Marine Corps Reserve Administrative Management Manual (MCRAMM) is "to augment and reinforce the active component (AC) with trained units and qualified individuals in a time of war or national emergency, and at such times as national security may require."[5]

The Marine Corps Reserve complements the Marine Corps operating force structure and capabilities. Charged with providing the means for rapid expansion of the Marine Corps during national emergency, the Marine Corps Reserve provides the added capability, flexibility, and depth that are the foundation for sustainment at any level of recall or mobilization. Total force integration is the dominant theme for all reserve planning, training, and administration.[6]

The Marine Corps Reserve is an integral element of the total force Marine Corps and is organized, equipped, and trained in the same manner as the active component Marine Corps allowing for the interchangeability of these components to best support the nation's security requirements as directed by the Commandant of the Marine Corps (CMC). Total Force Marine Corps is a subsection of the DoD total force policy implemented in 1973. This policy directs decisions regarding the availability of manpower resources to the DoD. Maintaining the integrated capabilities of the total force remains essential for U.S. defense strategy to succeed.

The Marine Corps Reserve is organized to act as a fourth Marine Expeditionary Force (MEF). The 4th MEF includes a Maine Division (MarDiv), a Marine Air Wing (MAW), and a Marine Logistical Group (MLG) along with the Marine Corps Mobilization Command (MOBCOM). These Major Subordinate Commands (MSCs) fall under Marine Forces Reserve (MARFORRES) (Figure 1). This structure allows

---

[5] "Marine Corps Reserve Administration Management Manual," MCO 1001R.1K (Quantico, VA: U.S. Department of Navy, 2009), Ch 1 para 1100.

[6] MCO 1001R.1K, Ch 1 para 1100.2.

MARFORRES to provide organized, equipped, and trained forces to "Commander, U.S. Marine Corps Forces Command (COMMARFORCOM) and the Commander, Marine Forces Pacific (COMMARFORPAC), or such other AC commanders as may be appropriate for the conduct of joint operations, exercises, and training."[7]
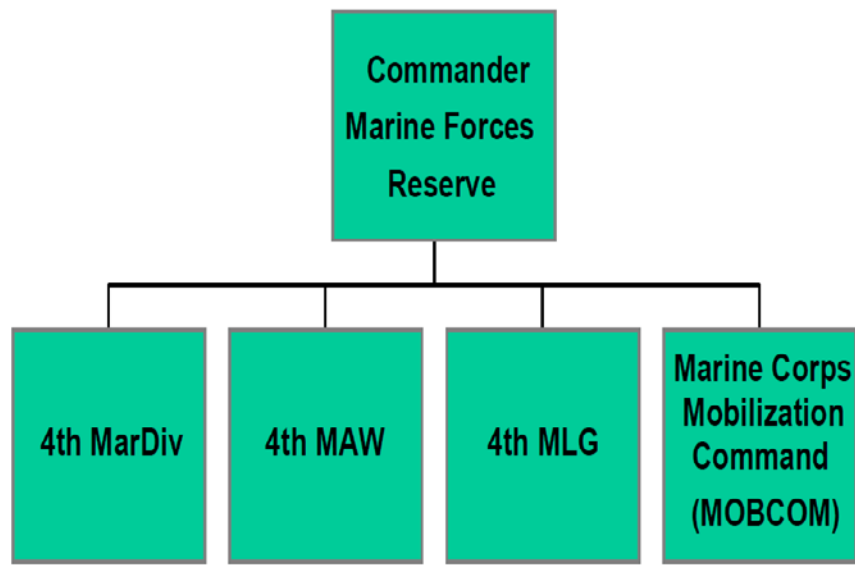
Figure 1.   Organization of Marine Forces Reserve[8]

B.   COMPONENTS

The Marine Corps Reserve is composed of three major components: the Ready Reserve, the Standby Reserve, and the Retired Reserve as shown in Figure 2.

---

[7] MCO 1001R.1K, Ch 1 para 1301.b.

[8] MCO 1001R.1K, Figure 1–2.
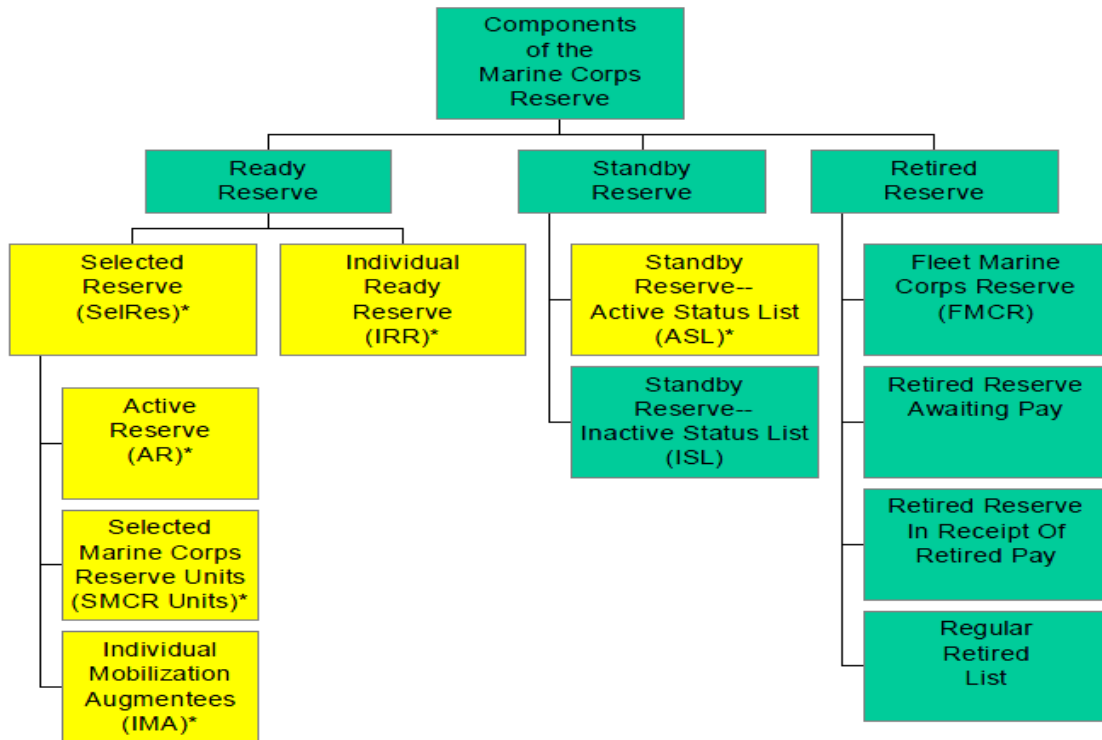
```
Note: Components highlighted in yellow (*) are elements of the
RASL.
```

Figure 2.   Components of the Marine Corps Reserve[9]

1.   Ready Reserve

The Ready Reserve is composed of the Individual Ready Reserve (IRR) and the Selected Reserves (SelRes). The Ready Reserve contains the majority of reserve Marines available for immediate recall to active duty in the time of war or national emergency or when authorized by law. The Selected Reserve population of the Ready Reserve is the focus of this thesis since they constitute the largest proportion of reserve manpower.

a.   *Individual Ready Reserve*

The IRR consists of Marines in the Ready Reserve who are available to mobilize, have completed training, or have previously served in the active component or

---

[9] MCO 1001R.1K, Figure 1–1.

SelRes. These Marines belong to the IRR either by having not fulfilled their Military Service Obligation (MSO) or, having completed their MSO, have volunteered to stay in the Ready Reserve.

b.   Selected Reserve

The SelRes consists of Active Reserve (AR), Individual Mobilization Augmentees (IMA), SMCR units, and Marines conducting Initial Active Duty for Training (IADT). This thesis focuses on the SelRes population, and more specifically, Marines assigned to SMCR units.

(1) Active Reserve. The AR program consists of full time active duty billets that support the organization, administration, retention, recruiting, and training of the Marine Corps Reserve.

(2) Individual Mobilization Augmentees. IMAs are pre-trained and qualified members of the SelRes assigned to augment an active component organization to support the mobilization (including pre-and/or post-mobilization) requirements of the organization. These individuals do not drill with a SMCR unit but with the AC unit to which they are assigned. The standard IMA tour is three years with the ability to extend for a maximum of five years. Upon completion of tour, the Marine will be transferred to the IRR or a different IMA.

(3) Selected Marine Corps Reserve Units. SMCR units contain the largest part of the SelRes end strength and staff the 4th Marine Expeditionary Force (MEF), which consists of 4th Maine Division, 4th Marine Air Wing, and 4th Marine Logistical Group and other force level units of MARFORRES.

2.   Standby Reserve

The Standby Reserve consists of Marines who do not meet the participation requirements of the Ready Reserve but desire to continue to their affiliation. These individuals are subjected to recall to active duty during time of war or national emergency. The Standby Reserve consists of the Standby Reserve-Active Status List (ASL) and Standby Reserve-Inactive Status List (ISL).

a. Standby Reserve-Active Status List

The ASL consists of individuals unable to participate in reserve training on a regular basis due to civilian employment, hardship, or other personal issues. Marines in the ASL remain in an active status for promotion and retirement purposes but must maintain the required annual reserve point requirements to remain in an active status yet are ineligible for pay, allowances, or travel allowances. Members of the ASL may be called to active duty if it is determined that the Ready Reserve has a shortage of personnel with requisite skill.

b. Standby Reserve-Inactive Status List

The Standby Reserve-Inactive Status List (ISL) consists of officers who have met their requirements of service obligation but were unsuccessful in meeting the minimum participation requirements to remain in an active status, but desire to return to the Ready Reserve in the future. Individuals in the ISL are ineligible for promotion, pay or retirement benefits.

3. Retired Reserve

The Retired Reserve consists of Marines who have either requested or been approved for retirement. Marines within the Retired Reserve may be recalled to active duty under U.S. Code 10, § 688. The retired reserve comprises of the Fleet Marine Corps Reserve (FMCR), the Retired Reserve Awaiting Pay, the Retired Reserve in Receipt of Retired Pay, and the Regular Retired List.

a. Fleet Marine Corps Reserve

The Fleet Marine Corps Reserve is composed of enlisted personnel who have completed 20, but no more than 30 years of active service and are in receipt of retainer pay. Upon 30 years of service, FMCR members are transferred to the retired list.

b. *Retired Reserve Awaiting Pay*

Reservists in this "gray area" have completed at least 20 qualifying years of service and have requested transfer to the Retired Reserve. Upon the reservists' 60th birthday, it is then possible to apply to begin distribution of retirement pay.

c. *Retired Reserve in Receipt of Retired Pay*

Reservists in the Retired Reserve who have completed at least 20 years of qualifying service and upon their 60th birthday have applied for and are in receipt of retirement pay. Once payment commences, these individuals are placed on the Retired List of the Marine Corps Reserve.

d. *Regular Retired List*

The Regular Retired List consists of all officers who have completed at least 20 years of active duty and enlisted members who have completed a total of 30 years of combined service on active duty and FMCR. At least 20 years must have been on active duty to qualify.

4. Active Status Requirements

a. *Military Service Obligation*

Marine Corps Order 1001R.1K states, "Anyone inducted; enlisted, or appointed into the Armed Forces on or after 1 June 1984 incurs an 8-year period of obligated service. Service-members who entered the service prior to 1 June 1984 incurred a 6-year obligation."[10] Any amount of this obligation not conducted either on active duty (AD) or active duty training (ADT) will be served in a Reserve Component.

b. *Mandatory Drill Participation Stop Date (MDPSD)*

MDPSD is the period of time during which the service members have met their mandatory drilling obligation with an SMCR unit. This period includes their total MSO, which covers their required drilling obligation, in addition to their total required

---

[10] MCO 1001R.1K, Ch 2 para 2101.1.

Ready Reserve time. "For example, in the case of a NPS reservist serving on a 6x2 contract, the 6 years represent the mandatory drill participation time while the 2 years are encompassed within their total MSO."[11]

c.   *Participation Requirements*

Each participant of the Marine Corps Reserve in an active status is required to attain a minimum quantity of participation points to fulfill the required obligation or to achieve a satisfactory year (Table 1). Annual participation requirements vary for each subcomponent within the Marine Corps Reserves. Individuals joining the Ready Reserves, which is comprised of both the SelRes and Individual Ready Reserve, automatically earn 15 points for enrolling.[12] Active Reserve (AR) Marines are considered on AD and are not obligated to a minimum point requirement.

SMCR and Individual Mobilization Augmentee (IMA) are required to perform a minimum of 48 periods of inactive duty training (IDT).[13] IDT's primary purpose is to provide individual and unit readiness training conducted by units to which the individual is affiliated or a member. IDT requirements usually occur during the weekends with each period representing a 4-hour block or one point. A weekend drilling period consists of four drills (four points) toward the required 48 periods of IDT, which equates to one weekend a month per FY. In addition to IDT, SMCR unit members must perform a minimum 14 days annual training (AT) per FY. SMCR unit members can combine any combination of ADT, incremental initial active duty training (IIADT), IADT, attendance at a formal school, or full time AD to fulfill the 14 days AT requirement per FY.[14] IMAs are required to perform a minimum of 12 days of AT per FY to satisfy their obligation.

Marines in the IRR with fewer than 20 years of service must accrue a minimum of 27 points per FY to remain in good standing. IRR Marines with over 20

---

[11] Joseph M. Lizarraga, "Patterns of Marine Corps Reserve Continuation Behavior: Pre- and Post-9/11" (master's thesis, Naval Postgraduate School, 2011).

[12] MCO 1001R.1K, Ch 9, para 9305.2.

[13] MCO 1001R.1K, Ch 5, para 4500.1.

[14] Ibid.

years of service must accumulate a minimum of 50 points annually to satisfy IRR requirements for continued enrollment or may be transferred to either the Standby Reserve, Retired Reserve, or be discharged from the Reserves.[15]

Category	IDT	ADT	Points	Other
SMCR	48	14	NA	
IMA	48	12	NA	
IADT	NA	Varies by MOS	NA	
IRR	0	0	27	Muster Duty
ASL	0	0	27	
AR	NA	NA	NA	Active Duty

Table 1.   Minimum Satisfactory Participation Requirements for Reserve Marines in an Active Status[16]

Meeting the required mandatory training as specified in Table 1 does not in itself constitute a member achieving satisfactory participation. The member must also comply with "all applicable Marine Corps regulations to include meeting standards of attendance, weight control and military appearance, fitness, decorum, attitude, and effort expended during training periods."[17] Members who fail to accumulate the necessary points as listed in Table 1 may risk discharge from the Marine Corps Reserves. SelRes members who have not fulfilled their initial enlistment agreement and accrue more than nine unexcused absences from IDT within a 12-month period will have their contractual period of participation extended.[18]

C.   SUMMARY

This chapter provided a brief overview of the Marine Corps Reserve structure and organization. While not a comprehensive discussion of the Marine Corps Reserve, this

---

[15] MCO 1001R.K, Ch 9.

[16] MCO 1001R.1K, Table 9–1.

[17] MCO 1001R.1K, Ch 4, para 4500.2.

[18] Jonathon D. Price, "Effects of Activation on Selected Marine Corps Reserve Prior Service Enlisted Continuation Rates in the Post-9/11 Era" (master's thesis, Naval Postgraduate School, 2010).

chapter highlighted the non-linear aspects of the reserve component that affords it the flexibility and adaptability to support the needs of the total force. As stated earlier, the focus of this thesis centers on the Selected Reserve population of the Marine Corps Reserve organization. The importance of this segment of the Marine Corps Reserve to the Marine Corps Total Force strategy demands that an effective management tool be available to forecast the required enlisted personnel inventory necessary to provide the operational force multiplier for the Marine Corps.

THIS PAGE INTENTIONALLY LEFT BLANK

III.   LITERATURE REVIEW

A literature search to locate relevant studies discussing the development and usage of Markov models for manpower planning on the reserve component of the Marine Corps was limited. Upon further review of manpower studies, three publications discuss the employment of Markov models to generate solutions to manpower scenarios. These three publications, "Statistical Techniques for Manpower Planning" by Bartholomew, "Attainable and Maintainable structures in Markov Manpower Systems with Pressure in the Grades" by Kalamatianou, and "The Validity of the Markov Chain Model for a Class of the Civil Service" by Pauline Sales form the basis for this thesis. In addition to these resources, three Naval Postgraduate School (NPS) theses focusing on various aspects of Marine Corps manpower issues were included in this literature review.

Kalamatianou addresses the issue of promotion pressure on a manpower structure and the consequences of this pressure on personnel within this structure:

> Pressure in a grade is the result of delays in expected promotions and is measured by the proportion of people in those length-of-service categories of a grade from which promotees are chosen. High values of pressure would tend to make the system unstable with respect to promotions. A high proportion of unpromoted employees could a have serious effect on the efficiency of the organization.[19]

Kalamatianou contends that a maintainable manpower structure defined as "one in which the overall size and pressure in the grades are constant over time with a fixed recruitment vector"[20] is attainable if the recruitment vector is repeatedly employed to maintain the initial structure. The manpower structure she describes in this article parallels the hierarchically graded manpower structure of the United States Marine Corps Reserve. This article provides relevance regarding policies of managerial control on recruitment and promotion, such as limited number of boat spaces for certain military occupational skills (MOS) and promotion rates.

---

[19] A. G. Kalamatianou, "Attainable and Maintainable Structures in Markov Manpower Systems with Pressure in the Grades," *The Journal of the Operational Research Society* 38, no. 2 (February 1987): 183–190.

[20] Ibid.

Bartholomew discusses that the object of manpower planning is matching the correct number of people with the appropriate skills to the jobs available at a given time to fulfill that organization's manpower needs.[21] The author acknowledges how uncertainty plays a major role in manpower planning and suggests applying statistical probabilities assistance in addressing this issue. Bartholomew's work discusses the stochastic nature of manpower planning and its effects on wastage and promotions on the organization. This approach is similar to the current Marine Corps reserve manpower model in that voluntary wastage and promotions are more or less individual decisions that are random variables and must be treated as such. In addition, he addresses the need to distinguish between quantities, which are fixed, or controlled, and those that are not.[22]

> For example, in some organizations the number of jobs in each grade is fixed in relation to the work available. The stock numbers cannot therefore be treated as random variables and the need to maintain their values will place constraints upon the flows.[23]

This article focuses on the use of models for prediction based on the assumption that the parameters within a system remain constant. In actuality, control of these parameters resides in the management hierarchy allowing them to manipulate these parameters to achieve their desired end state.

In the 1971 publication, "The Validity of the Markov Chain Model for a Class of Civil Service," Sales advocates that using a Markov model will provide a more concise prediction of future changes in the grade structure of the scientific civil service for the years 1963–1968. Sales suggests:

> We are concerned with the number of members of the system in the grades at successive points in time, and with the flows between the grades from one point to the next. In the Markov Chain model the flows are assumed to be governed by transition probabilities and each class is homogenous and independent with respect to these probabilities. By using estimates of the

---

[21] Van Q. Nguyen, "Analysis of the U.S. Marine Corps' Steady State Markov Model for Forecasting Annual First-Term Enlisted Classification Requirements" (master's thesis, Naval Postgraduate School, 1997), 10.

[22] D. J. Bartholomew, "The Statistical Approach to Manpower Planning," *Journal of the Royal Statistical Society* 20, no 1 (March 1971): 3–26.

[23] Ibid., 4.

transition probabilities obtained from the data one can predict, for example, future changes in the grade structure.[24]

Sales reproduces the scientific civil service as a hierarchical graded manpower structure composed of mutually exclusive and exhaustive grades or states allowing each member of the structure to reside in one and only one grade at any given time. This structure is similar to the enlisted manpower structure of the Marine Corps Reserve. The issue of how best to construct each grade or state to obtain the best fit possible is the crux of model construction.

> For instance, each class is a grade and everyone in the grade is assumed to have the same probability of promotion, leaving, etc., whereas in reality they do not since the variable mentioned are dependent on age. Thus if the classes were age groups within grades instead of whole grades the transition probabilities would be more likely to be constant in the classes. Also, in this example, each grade consisted of people with 5 different scientific functions (e.g. physicists, chemists, etc.), so a breakdown of the grades to allow this fact would probably also give a better fit by the model.[25]

She tests her hypothesis that transition rates over time (independent of time) remains constant by utilizing two methods of testing, the graphical method and the time-homogeneous probabilities: Goodness of fit statistic method. Both methods show minimum variance of the transition matrix probabilities validating her hypothesis. The only year that deviates from the norm is 1965. Estimates for wastage and promotion for 1965 are higher than expected, which the author surmises are the results of outside factors—the establishment of two new scientific bodies.

A. FORECASTING UNITED STATES MARINE CORPS SELECTED RESERVE END STRENGTH[26]

Emery develops a manpower model using exponential smoothing to forecast losses to the Selected Marine Corps Reserve end strength. This proposed model's

---

[24] P. Sales, "The Validity of the Markov Chain Model for a Class of the Civil Service," *Journal of the Royal Statistical Society* 20, no. 1 (March 1971): 85–110.

[25] Ibid., 89.

[26] Nathan N. Emery, "Forecasting United States Marine Corps Selected Reserve End Strength" (master's thesis, Naval Postgraduate School, 2010).

prediction was more desirable due to a smaller standard deviation and range than the Reserve Manpower Model's predictions to actual end strength numbers. The model's accuracy may be affected when adjustments to accession and attrition projections are considered, which could reduce the model's utility to reserve manpower planners as a tool to project future FY's end strength structure.

B. POST 9/11 FIELD GRADE OFFICER REQUIREMENTS IN THE MARINE CORPS RESERVE[27]

Luther creates a model using ordinary least square (OLS) regression to develop a tool for Manpower and Reserve Affairs (MR&A) to use as a reference in determining the appropriate grade strength of field grade officers in the Reserve Active Status List (RASL) by estimating affiliations and participation rates. This tool assists MR&A in planning for requirements and potential mobilization of this population. This thesis provides a tool to assist in the manpower management of the field grade officer population of the Marine Corps Reserve that is outside the scope of this research.

C. ANALYSIS OF THE U.S. MARINE CORPS' STEADY STATE MARKOV MODEL FOR FORECASTING ANNUAL FIRST-TERM ENLISTED CLASSIFICATION REQUIREMENTS[28]

Nguyen study examines the Markov model utilized by manpower planners at Headquarters Marine Corps (MPP-23) to forecast the annual first-term enlisted classification requirements for the active duty component. This model applies annual transition rates across time to an initial inventory to forecast the future inventory. To account for accessions, additional inventory is added to the system for each application of transition rates. Two flaws were identified in this study, first-year continuation rates were under estimated across all primary military occupational skills (PMOS) and rounding errors caused inexact classification estimates. Nguyen corrected these deficiencies in the revised model developed. Although Nguyen's research focused on forecasting first-term

---

[27] Chris D. Luther, "Post-9/11 Field Grade Officer Requirements in the Marine Corps Reserve" (master's thesis, Naval Postgraduate School, 2011).

[28] Nguyen, "Analysis of the U.S. Marine Corps' Steady State Markov Model for Forecasting Annual First-Term Enlisted Classification Requirements."

personnel classification for the active component, some aspects of his revised model could be used in conjunction with the model developed in this study since both populations share similar characteristics.

In summary, the literature review briefly highlights some of the most prominent studies in the area of Markov models in manpower planning. The above-mentioned publications either discuss or devise concepts to shape their respective manpower force structure accurately. However, each of them employs a different driver to reach their end state. As mentioned, the dearth of previous research dealing with the employment of Markov models to account for the discrepancies between the projected and the required structure of the non-prior service (NPS) and PS enlisted populations of the Marine Corps Reserve Selected Reserve. The end state for this thesis is the development of a model that provides a more precise forecast of the enlisted reserve force structure considering the concepts and ideas discussed in the cited literature.

THIS PAGE INTENTIONALLY LEFT BLANK

IV.   DATA AND METHODOLOGY

A.   INTRODUCTION

This chapter reviews the data used in the model and the methodology behind the development of a model for forecasting inventory for Marine Corps Reserve NPS and PS enlisted Marines. It discusses the data collection process, provides descriptions of variables used and how they were incorporated into the model.

B.   DATA SOURCES

1.   Reserve Affairs Personnel Plans and Policy (RAP)

RAP provided the data employed for use in this study. RAP primary data source was the Marine Corps TFDW. All personal identifiable information was sanitized from all data used in this study.

a.   *Total Force Data Warehouse (TFDW)*

The data used in this study was sourced from the Marine Corps TFDW system. The Manpower Information Division at Manpower and Reserve Affairs (M&RA) administrates the TFDW system. The TFDW is an enormous database containing financial, service, and demographic information for all personnel (enlisted, officer, active, and reserve) in the Marine Corps. Personnel and pay data are submitted on a daily basis into the Marine Corps Total Force System (MCTFS)[29]. Each month, this data is transferred to TFDW, which allows the Marine Corps to obtain a monthly picture of the total force. The TFDW is an accumulation of data taken on the last day of every month. For this thesis, 72 data fields were retrieved. The data represents 2,701,262 monthly-person observations from the period of October 31, 2005 sequence 200 to September 30, 2011 sequence 271.

---

[29] The MCTFS is the single fully integrated personnel and pay system supporting both active and reserve component of the Marine Corps, and personnel management for all retired Marines. MCTFS data is stored in TFDW.

2. Descriptive Variables

The following descriptive variables are employed in this study were either acquired from TFDW or constructed for use in the Markov models. The data from TFDW consists of 21 variables and input into STATA to merge, code, clean, and analysis is then exported into a Microsoft Excel format to incorporate into the Markov model.

a. *Present Grade Code*

Present grade code is the Marines' current grade. Figure 3 is a snapshot of the grade distribution of the Marine Corps Reserve for FY06–11. This thesis focuses on the enlisted population. Therefore, the officer population was excluded from the data acquired from TFDW.
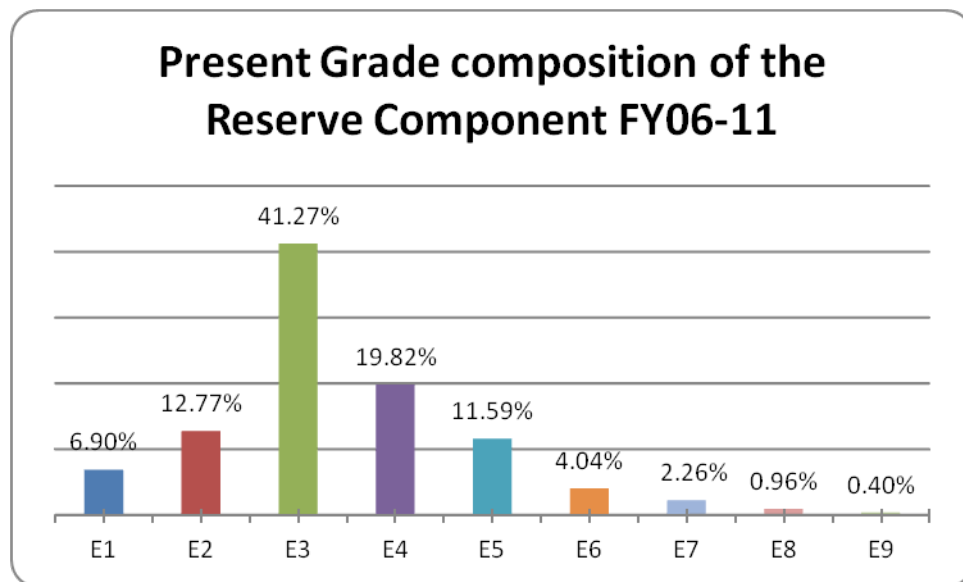

Figure 3.   Present Grade Composition of the Reserve Component FY06–11

b. *Mandatory Drill Participate Stop Date (MDPSD)*

The MDPSD is the date on which an NPS Marine has met the mandatory drilling obligation with an SMCR unit. Once this initial period of obligated active participation within an SMCR unit has been fulfilled, the remaining MSO may be served in the IRR or as a drilling member in the SelRes.

c.   *Military Service Obligation (MSO)*

Individuals who enlist in the Marine Corps and sign a contract incur a military obligation known as a MSO. Any part of this service not served on AD or ADT will be performed in a RC.

d.   *Pay Entry Base Date (PEBD)*

A pay base date is the actual or constructive date of original entry in the service, which is creditable for pay purposes. This variable was utilized to code reserve component codes as listed on Table 1.

e.   *Total Satisfactory Years*

A reservist must earn a minimum of 50 points per anniversary year and serve a full 365/366 day period to complete a qualifying year for retirement purposes.

f.   *Anniversary Date*

Every reservist has a unique anniversary date and the anniversary year periods are calculated from this anniversary date. This date is established by the date the member entered into active duty or into an active status in the RC.

g.   *Prior Active Component (AC)*

Reservists who have served on active duty and completed their active duty obligation prior to joining the RC are considered part of the AC. For this thesis, these Marines are identified as PS.

h.   *Reserve Component Code*

The reserve component code is a two-character code that indicates a Marine's reserve enlistment contract. Table 2 highlights the four major reserve component codes used for this study.

Reserve Component Code	Contract Type
K4	6x2 = 6 years drilling in the SMCR and 2 years remaining in the Ready Reserve
K9	4x4 = 4 years drilling in the SMCR and 4 years remaining in the Ready Reserve
B5	5x3 = 5 years drilling in the SMCR and 3 years remaining in the Ready Reserve
K8	3x5 = 3 years drilling in the SMCR and 5 years remaining in the Ready Reserve

Table 2.   Reserve Component Code and Contract Type[30]

Figure 4 shows the distribution of the above mentioned reserve component codes. Ninety-seven percent of the NPS personnel in the Marine Corps SelRes are on 6x2 contracts. The rest are on either 4x4 contracts (2.03%), 3x5 contracts (0.14%) or 5x3 contracts (.05%).
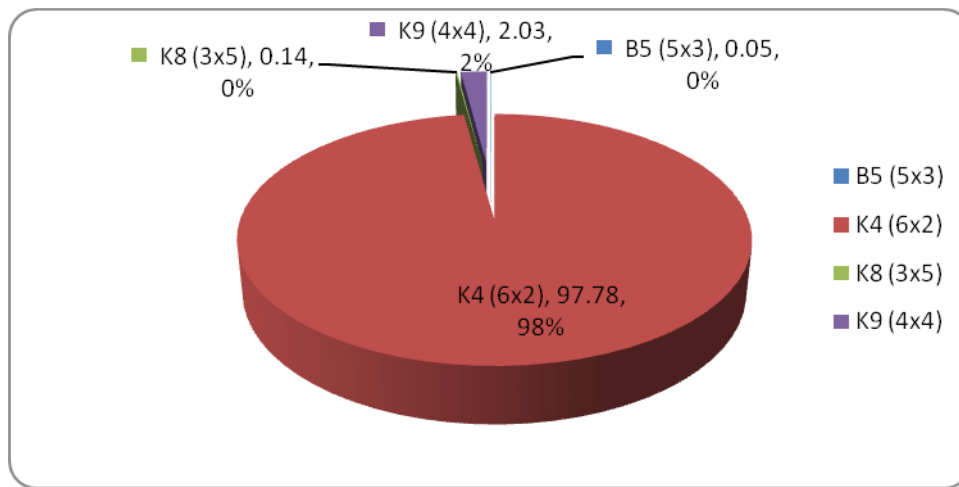

Figure 4.   Distribution of Reserve Component Codes

3.   Constructed Variables

a.   *Obligation Completed (obligation_completed)*

This variable is constructed to measure NPS Marines obligation completed. To construct this variable, the sequence date was subtracted from the MDSD then divided by 30.5 (average month) or (seq_date-mdsd)/30.5). This number signifies

---

[30] John M. Lizarraga, "Patterns of Marine Corps Reserve Continuation Behavior: Pre- and Post-9/11" (master's thesis, Naval Postgraduate School, 2011), 16.

that the Marine has a MSO of 72 months that corresponds with a 6x2 contract. If the obligation completed variable was missing then 72 months was added to that Social Security Number (SSN).

b.   Satisfactory Months (sat_months)

The variable satisfactory months measures PS Marines satisfactory attendance and participation in the required training for the Marine's individual training category. Sat_months is derived by multiplying total satisfactory year by 12 and then adding 365.25 minus anniversary date minus sequence date divided by 30.5 to provide a numerical unit to calculate PS Marines time in the reserve.

Both NPS (obligation_completed) and PS (sat_months) capture the enlisted population's annual participation requirements. This information is collected by the administrative section of SMCR units and, therefore, is subject to deviations.

c.   Fiscal Years (FY)

Dummy variables for each fiscal year were created by importing the appropriate sequences from TFDW and merging them into STATA. This thesis used sequences 200 through 271. (Table 3)

fy06	31-Oct-05	30-Nov-05	31-Dec-05	31-Jan-06	28-Feb-06	31-Mar-06	30-Apr-06	31-May-06	30-Jun-06	31-Jul-06	31-Aug-06	30-Sep-06
Seq	200	201	202	203	204	205	206	207	208	209	210	211
fy07	31-Oct-06	30-Nov-06	31-Dec-06	31-Jan-07	28-Feb-07	31-Mar-07	30-Apr-07	31-May-07	30-Jun-07	31-Jul-07	31-Aug-07	30-Sep-07
Seq	212	213	214	215	216	217	218	219	220	221	222	223
fy08	31-Oct-07	30-Nov-07	31-Dec-07	31-Jan-08	29-Feb-08	31-Mar-08	30-Apr-08	31-May-08	30-Jun-08	31-Jul-08	31-Aug-08	30-Sep-08
Seq	224	225	226	227	228	229	230	231	232	233	234	235
fy09	31-Oct-08	30-Nov-08	31-Dec-08	31-Jan-09	28-Feb-09	31-Mar-09	30-Apr-09	31-May-09	30-Jun-09	31-Jul-09	31-Aug-09	30-Sep-09
Seq	236	237	238	239	240	241	242	243	244	245	246	247
fy10	31-Oct-09	30-Nov-09	31-Dec-09	31-Jan-10	28-Feb-10	31-Mar-10	30-Apr-10	31-May-10	30-Jun-10	31-Jul-10	31-Aug-10	30-Sep-10
Seq	248	249	250	251	252	253	254	255	256	257	258	259
fy11	31-Oct-10	30-Nov-10	31-Dec-10	31-Jan-11	28-Feb-11	31-Mar-11	30-Apr-11	31-May-11	30-Jun-11	31-Jul-11	31-Aug-11	30-Sep-11
Seq	260	261	262	263	264	265	266	267	268	269	270	271

Table 3.   Dummy Fiscal Years[31]

---

[31] Total Force Data Warehouse (TFDW).

C.   MARKOV MODEL THEORY

A Markov model is a simulation that the probabilities of future conditions from a given state are independent from the history of the system.[32] An important assumption used with a series with the Markov property[33] is best described as stating the process is "memory less," meaning that probability of transitioning to the future states only depends on the current state. In other words, the past states carry no information about future states. The Markov process is comprised of states and the movements between these states. This process can be illustrated in a matrix of transition probabilities composed of rows and columns that represent the states and the coefficients refer to the probabilities with which personnel move between the various states within this system. The system may have changed from the current state it was previously in, or it may have stayed in the same state, or advanced to a future state. The movement or changes of the states are called transitions. In the context of this thesis, the transitions are usually consequences of wastage or accessions into the system. In a fixed inventory model, the Markov process determines the number of personnel who must be accessed to meet the legislative end strength structure of the Marine Corps Reserves.[34]

The Markov model, as other manpower models employed by the military, mathematically describe how changes occur in a personnel system. Unlike other manpower models, the Markov model does not consider any exogenous variables, such as demographic trends or unemployment rates.[35] Markov models are used by manpower planners to forecast what may occur if forecasted trends continue as they have been observed in the past. Bartholomew states:

---

[32] Frederick S. Hillier and Gerald J. Lieberman, *Introduction to Operations Research* 5th ed. (New York: McGraw-Hill, 1990).

[33] The probability that system will transition to state j depends only upon current state.
$$\Pr\{X_{n+1} = j \mid X_n = i\} = \Pr\{X_1 = j \mid X_0 = i\}.$$

[34] Richard Gilliard, "Steps towards determining the right number of dental recruits the Navy should access to meet the projected targets for Navy Dental Corps Officers" (master's thesis, Naval Postgraduate School, 2007), 21.

[35] Jeffery Sapp, "A Calculator Adaption of the Markov Chain Model for Manpower Analysis" (master's thesis, Naval Postgraduate School, 1983), 12.

There are two features of most manpower planning problems which render them suitable for statistical treatment. The first is the concern with aggregates. Manpower planning, unlike individual career planning, is concerned with numbers, that is, with having the right numbers in the right places at the right time. The second feature of manpower planning which calls for statistical expertise is the fact of uncertainty. This arises both from the uncertainty inherent in the social and economic environment in which the organization operates and from the unpredictability of human behavior[36]

The purpose of this subsection is to familiarize the reader with the characteristics and capabilities of the fixed inventory model utilized for this thesis.

1. Fixed Inventory Model

The Marine Corps Reserve manpower model is based on stocks and flows. Stocks are the distribution of enlisted personnel in every rank and the total population of enlisted reserve personnel. Flows are the transitions to the next state. Within this system are two types of flows of equal importance, flows into the system (recruitment) and flows between the various parts of the system (promotions, transfers, and wastages).[37] A fixed inventory model assists to facilitate the understanding and the control of stocks and flows after the implementation of various institutional policies. Utilizing a fixed inventory model, manpower planners can war game different manpower scenarios regarding the enlisted population by adjusting the inputs to this model.

The fixed inventory model is based on transition probabilities (primary input) to estimate a number of manpower outputs. An important output of the model is the calculation of appropriation accessions required to satisfy the required end strength of this population throughout a specified time period.

---

[36] D. J. Bartholomew, A. F. Forbes, and S. I. McClean, *Statistical Techniques for Manpower Planning* (Chichester: John Wiley & Sons, 1991).

[37] D. J. Bartholomew, "The Statistical Approach to Manpower Planning," *Journal of the Royal Statistical Society,* Series D (The Statistician), (Blackwell Publishing, 1971): 14.

2. **Methodology**

   a. *Conceptual Model*

The Markov model developed for this thesis reviews the flow of personnel through the system and identifies what the steady state should be for each state by identifying the number of personnel in the system at each state and how each of them transitions from one state to the next. Personnel can flow through the system in two ways, either by advancing to the next state or leaving (attrite) (Figure 5).
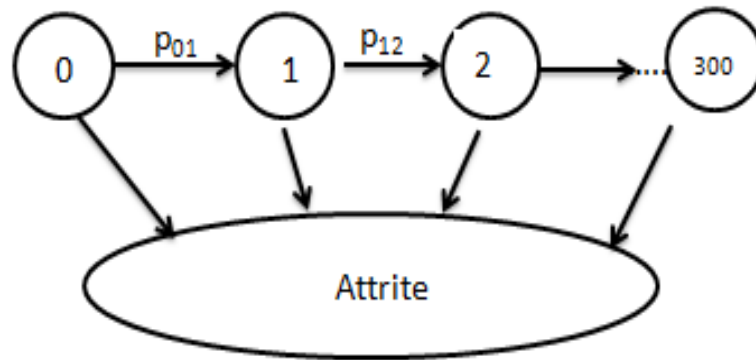

Figure 5.   Conceptual Model

Changing the inputs of the model can provide RAP the ability to estimate numerous outcomes concerning the NPS and PS enlisted population for future fiscal years and under alternative policies. Based on the transition probabilities of the model, RAP can utilize this model to estimate a number of manpower outputs. A single transition represents one month, so each transition probability represents probability that a Marine will continue to the next state (month of service). One output of the fully implemented spreadsheet model is the number of accessions necessary to maintain the appropriate NPS enlisted population achieved by using the transition probabilities in conjunction with the targeted enlisted population goal.

b.   Transition Matrix

The transition matrix specifies each conditional probability associated with moving from one state to another. In Figure 6, P_{12} is the probability that an individual currently in a present state S_1 will be in S_2 in the future.

Figure 4 is an example of a system that has three categories with the transition proportions between each category arranged in an array.

$$
\begin{array}{cc}
 & \textbf{Future State} \\
 & \begin{array}{ccc} S_1 & S_2 & S_3 \end{array} \\
\textbf{Present State} \quad \begin{array}{c} S_1 \\ S_2 \\ S_3 \end{array} & \left(\begin{array}{ccc} p_{11} & p_{12} & p_{13} \\ p_{21} & p_{22} & p_{23} \\ p_{31} & p_{32} & p_{33} \end{array} \right)
\end{array}
$$

Figure 6.   Transition Matrix

c.   The Fixed Inventory Equation

The fixed inventory equation is employed to predict stock sizes in the different categories while controlling the number of people recruited during the forecasted period of time.

$$\mathbf{n}(t) = \mathbf{n}(t-1)\mathbf{P} + R(t)\mathbf{r}$$

Elements of the fixed inventory equation are as follows.

- n(t): n(t) is referred to as the stock or inventory vector at time t. Time is usually considered in discrete increments, i.e., t = 0,1,2,.... For this study, time is calculated by the unit month. This is the predicted stocks.

- n(t-1): n(t-1) is a vector of the stocks, (N), at the current time, (t-1). When t=1, n(0) represents the initial stock vector.

- P: $P = \{\hat{p}_{ij}\}$, whose entries are transitions probabilities and is referred to as the transition matrix. (Figure 6). The transition probability p_{ij} is the

ratio of personnel in state s_i at time n that will transition to state s_j by time n+1. The element, $\hat{p}_{ij}$ is the proportion of personnel in category "i" at the beginning of a time period that will move to category "j" by the end of the period.

- R(t): R(t) is the total number of personnel accessed and entering the system during a time, (t). It is important to understand that NPS and PS accessions are sourced from different populations and at dissimilar times.

- r: r is the recruitment vector that determines the proportion of total recruitment distributed among each category. For example, if r = (.75, .25, 0, 0), then .75 percent of the new personnel recruited will enter category one, 25 percent will enter category two, and zero percent will enter category three or category four.

D.   SUMMARY

In summary, the intent of this chapter is to provide source and background information on the data used in this study and provide an understanding of the methodology used to develop the Markov models for the NPS and PS enlisted populations.

V. MODEL IMPLEMENTATION AND VALIDATION

This chapter outlines the implementation of the Marine Corps Reserve NPS and PS enlisted population models in Excel and assesses the validity of the models with respect to the stationarity assumption. While the final models are ultimately loaded with FY11 data, the validation process was applied to the FY11 model, as well as models built with FY09 and FY10 data in an effort to improve the generality of the assessment.

A. NPS AND PS EXCEL MODELS

Each model is implemented in a stand-alone Excel workbook. The workbook contains several tabs interfaced to the Markov model to simplify the calculations. Sheets contain data, such as continuation rates, obligation growth, and on hand strength, that provide pertinent information relevant to its population.

Figure 7. Main Tab

The spreadsheet incorporates the following tabs.

1.   Main Tab

The main tab (Figure 7) integrates all the data accumulated on the corresponding tabs by inputting them into the fixed inventory formula:

$$\mathbf{n}(t) = \mathbf{n}(t-1)\mathbf{P} + R(t)\mathbf{r}.$$

This sheet houses the transition matrix and inventory vectors listed in its entity n_0 through n_{300} (Figure 8). In addition, months of service and on hand strength are represented on the main tab. The following tabs supply the main tab with pertinent data used in the formula.

Figure 8.   Main Tab with the Transition Matrix and Inventory Vectors

2. Attrition_K4 Tab

This tab contains the months of service and continuation rates for NPS and PS enlisted Marines.

3. Growth K4 Tab

This tab contains the growth rate of 6x2 Marines coming in multiplied by the inverse of PS Marines coming in plus PS Marines coming in multiplied by the PS AC growth rate. The PS AC growth rate is how many satisfactory months of service a PS Marine has upon joining the Reserves.

4. PS RC Growth Rate Tab

This tab contains the distribution rate, NPS K4 distribution, and PS RC distribution.

5. Obligor Growth Tab

This tab calculates of the amount of months of service a NPS enlisted Marine currently has served in the Reserves.

B. MODEL VALIDATION

The validation results reveal that a model based on an annual aggregate monthly transition rates fails the stationarity assumption required of Markov models. (See Chapter IV). The attrition behavior of NPS and PS enlisted population is seasonal due to the pattern of accessions, i.e., high school graduates enlist in the summer. The PS enlisted population demonstrates a similar accession pattern.

C. MODEL VALIDATION PROCESS

The models are "loaded" with FY11 data, which is to say, the transition probabilities ($\hat{p}_{ij}$) represents the probability that an element transitions from i to j in a single month. This probability is called the aggregate monthly transition probability because it is a weighted average of the given FY's 12 individual monthly transition

probabilities. For the Markov Model to satisfy the stationarity requirement, the transition rates for each i to j transition for each month must be sufficiently similar to the aggregate transition probability.

The steps used to validate the model in this study are as follows.

First, the annual aggregate monthly transition rate is calculated:

$$\hat{p}_{ij} = \frac{\sum_T f_{ij}(t)}{\sum_T n_i(t)}$$

for each i to j transition; where t denotes the months from October to September for the given FY. Then we calculate the unique monthly transition probabilities $\hat{p}_{ij}(t)$, along with standard errors for each; as given by:

$$SE(p_{ij}(t)) = \left(\frac{p_{ij}(1-p_{ij})}{n_i(t)} \right)^{1/2} .$$

Next, the interval for each transition probability is constructed: $\left\{ \hat{p}_{ij}(t) - \hat{se}(t), \hat{p}_{ij}(t) + \hat{se}(t) \right\}$. If $\hat{p}_{ij}(t)$ are normally distributed, then each interval should contain $\hat{p}_{ij}$ sufficiently stationary to the annual aggregate monthly transition rate. Finally, each monthly confidence interval is compared to determine if it contains $\hat{p}_{ij}$.

The graphical method (Figure 9) is used to confirm monthly rates are sufficiently close to the aggregate (red line). A reasonable definition of "sufficiently close" is being within one standard error from the aggregate. Figure 3 shows the monthly transition probabilities for state 79 of the FY11 model. The red line indicates the FY11 aggregate probability of 0.93696. The intervals for months October through April all contain the aggregate, while the intervals for months May through September do not. Thus, approximately 60% of the estimated transition probabilities contain the aggregate.
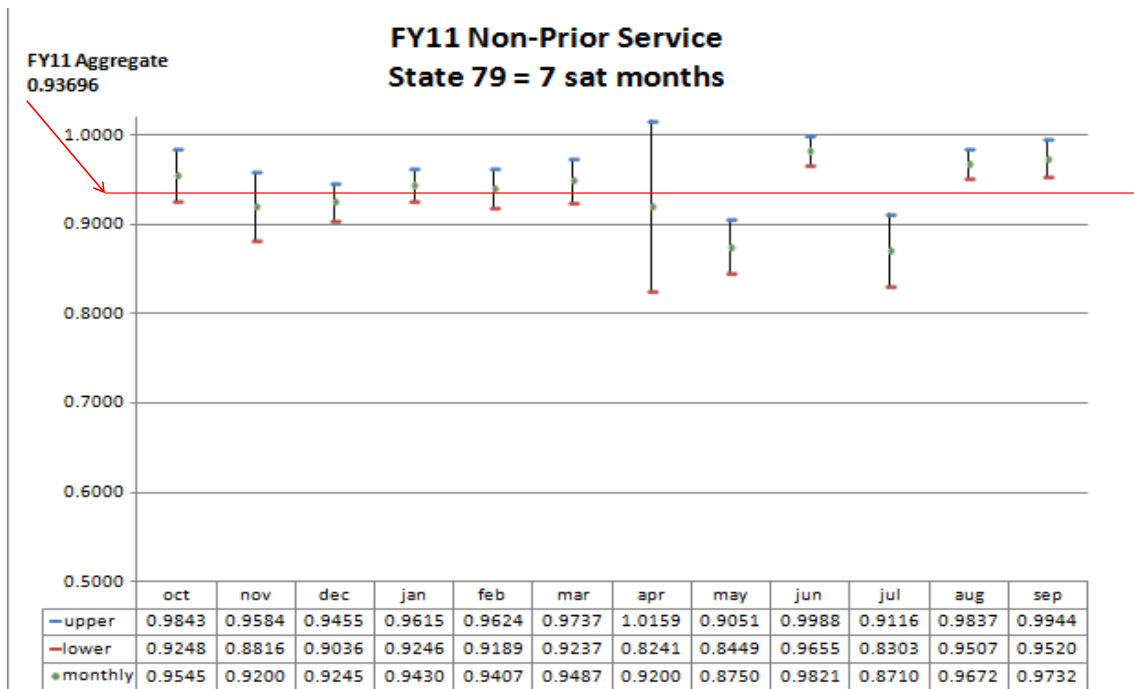
34

Figure 9.   Estimated Transition Probabilities with Standard Errors

Similar calculations are made for each state for both models. Both the overall number of monthly transition probability estimates that contain the respective aggregate probability are examined, as well as the proportion of satisfactory estimates for each state.

1.   Measure of Effectiveness—Proportion of Satisfactory Estimates

Both the NPS and PS validation processes required the calculation of 3,612 transition probability estimates, or 12 monthly estimates for each of the 301 states. Figure 10 depicts the proportion of satisfactory estimates as a percentage of total probability estimates. An estimate is satisfactory when the interval for the monthly $\hat{p}_{ij}(t)$ contains the aggregate $\hat{p}_{ij}$. The following charts (Figures 10 and 11) show the results of the validation process for both NPS and PS populations as proportions of satisfactory estimates for each state. The charts illustrate the total number of states within each FY and the number of

satisfactory states for each FY. While the model is implemented with FY11 data, the same process to FY10 and FY09 data is applied in an effort to improve the generality of the analysis.

Figure 10.   Proportion of Satisfactory Estimates for Non-Prior Service[38]

Figure 10 shows the proportion of satisfactory estimates for the NPS population for FY09, FY10, and FY1. Only approximately 25% of the transition probabilities estimated for each model are satisfactory. Thus, scant evidence exists to justify the conclusion that the models of the NPS population that utilize annual aggregate transition probabilities are stationary.

Figure 11 depicts the proportion of satisfactory estimates for the PS model for the years FY09 through FY11.

---

[38] The lack of representation in certain states within the NPS population during model validation led to the exclusion of such states. Therefore, the total states vary between the FYs.

Proportion of Satisfactory Estimates for Prior Service

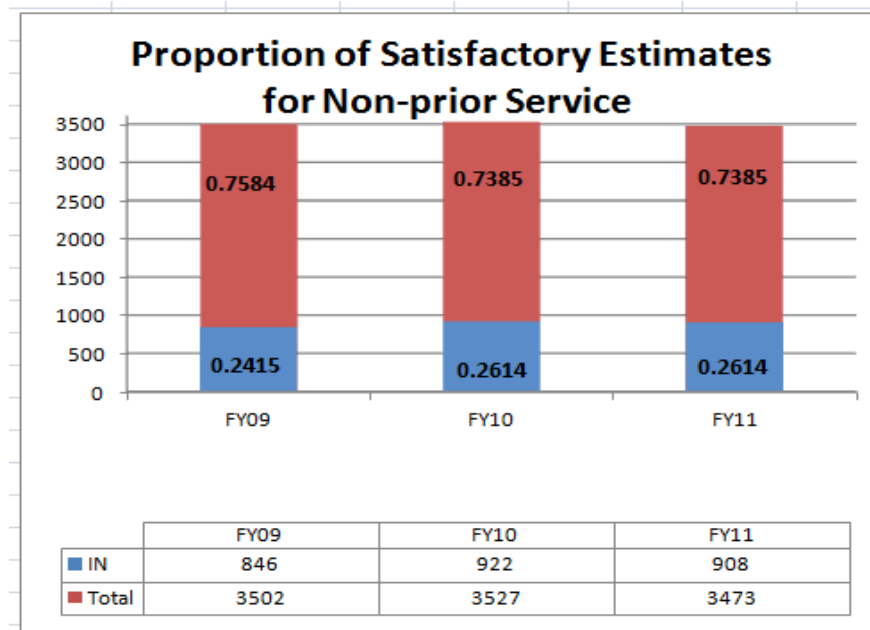|	FY09	FY10	FY11
IN	569	676	636
Total	3465	3428	3276
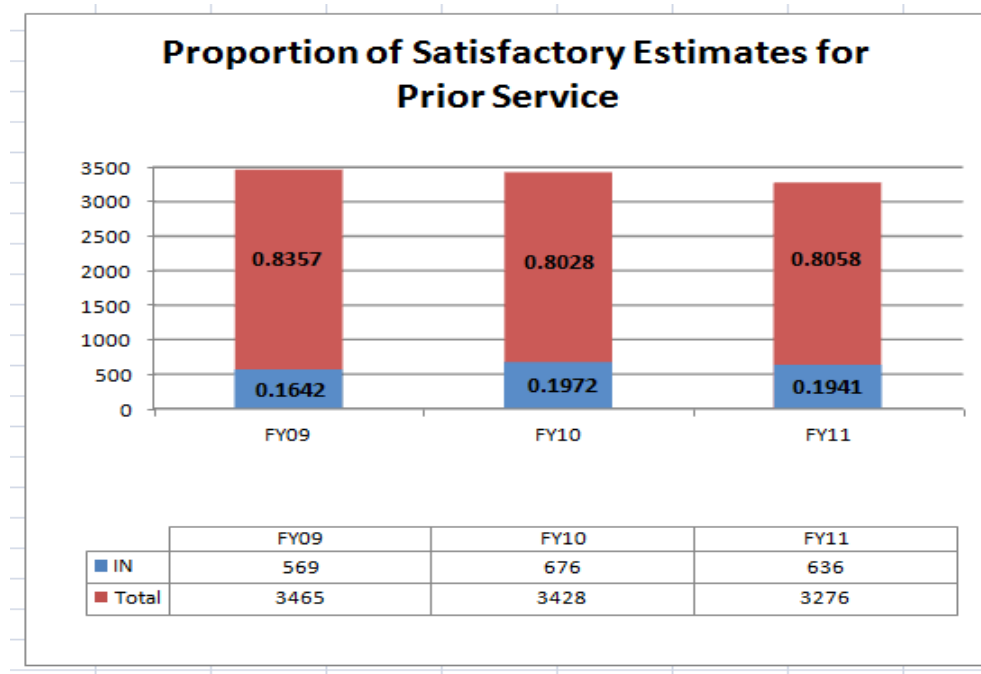
Figure 11.   Proportion of Satisfactory Estimates for Prior Service [39]

Figure 11 shows the proportion of satisfactory states for the PS population for FY09, FY10, and FY1. These models have no more than 20% satisfactory transition probabilities. These results lead to the conclusion that the model is not valid.

2.   Measure of Effectiveness—Percent of Satisfactory Monthly Estimates

Ultimately, the decision as to whether or not a state contains a sufficient number of satisfactory estimates to be considered stationary is a subjective decision. Of course, ideally, the goal is to see every state in a model have 12 satisfactory monthly estimates. Ultimately, states with 70% (9) or more states are probably sufficiently stationary to satisfy the requirements of the assumption. However, in some cases, it is possible that an even lower threshold would be tolerable.

For example, consider the model for Non-Prior Service. This model contains 301 states. Each state has 12 monthly estimates that correspond to estimates for October through September. Although we prefer all 12 monthly estimates for a given state to

---

[39] The lack of representation in certain states within the PS population during model validation led to the exclusion of such states. Therefore, the total states vary between the FYs.

satisfactorily contain the aggregate, it rarely occurs in practice. Ultimately, the threshold for what constitutes a sufficient number of satisfactory months is subjective and arbitrary.

Figure 12 depicts the number of satisfactory states for threshold levels 30% (4 months), 50% (6 months), 70% (9 months), and 90 % (11 months). If the threshold to declare a state "sufficiently stationary" was only 30% of the monthly estimates for that state needed to be stationary, then only 126 states in the FY11 model could be considered stationary. Thus, even at an absurdly low threshold, well less than half of the transition estimates could be considered stationary. Figure 12 also shows the same results for models built from FY09 and FY10 data.

Satisfactory States for Non-Prior Service

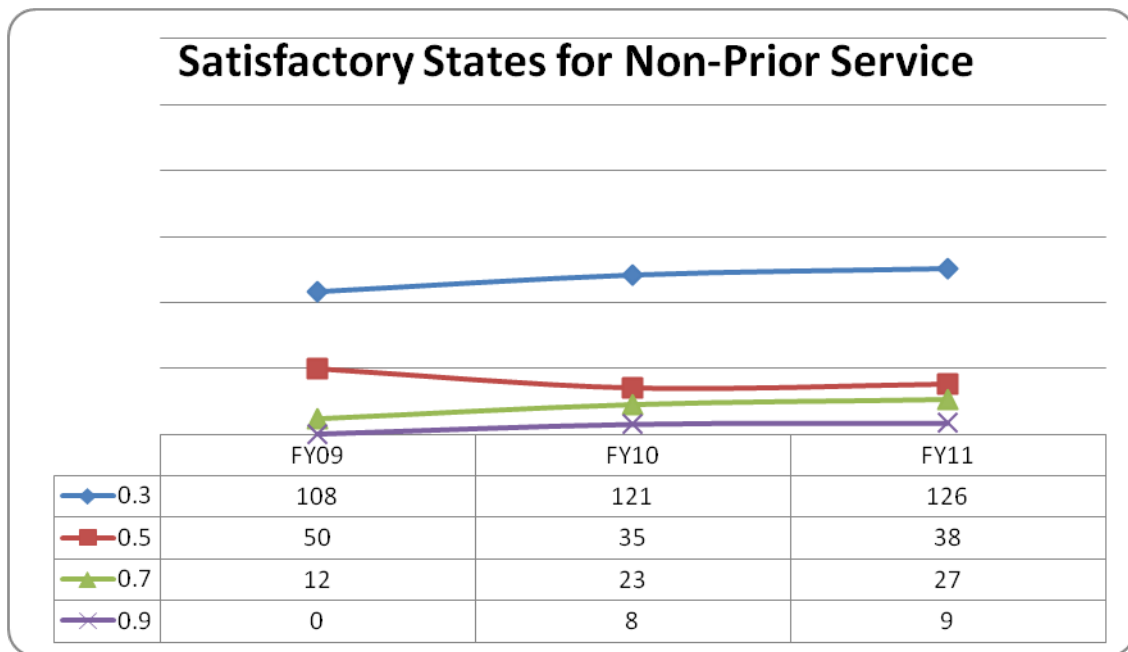|	FY09	FY10	FY11
—◆—0.3	108	121	126
—■—0.5	50	35	38
—▲—0.7	12	23	27
—✕—0.9	0	8	9

Figure 12.   Satisfactory States for Non-Prior Service Personnel

The assumption would be that since the NPS has a larger population (i.e., sample size) that it would lead to a better estimate (i.e., one with less variability and a smaller confidence interval) than the PS population. As the results show, this is not the case.

Figure 13 depicts the number of satisfactory states for threshold levels 30%, 50%, 70%, and 90 %t. If the threshold to declare a state "sufficiently stationary" was only 30% of the monthly estimates, then only 73 of the states in the FY11 model would be

considered stationary. Thus, as with the NPS Model, even with an absurdly low threshold, well less than 25% of all transition estimates would be considered stationary. Figure 13 also shows the same results for models built from FY09 and FY10 data.
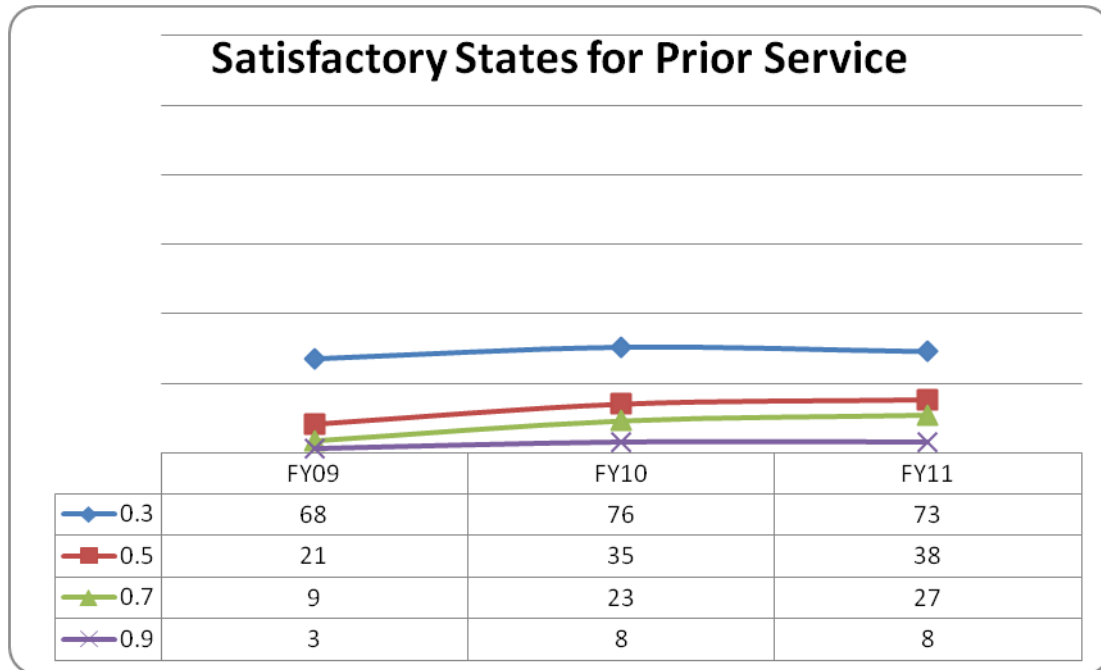
Satisfactory States for Prior Service

	FY09	FY10	FY11
0.3	68	76	73
0.5	21	35	38
0.7	9	23	27
0.9	3	8	8

Figure 13.   Satisfactory States for Prior Service Personnel

D.   SUMMARY

Model validation is an extremely important step in the model building sequence. The use of a model that does not fit the data well cannot provide the answers to the underlying questions under investigation. As demonstrated by the validation results, a model based on an annual aggregate monthly transition rate fails the stationarity assumption required of Markov models. These results suggest that the attrition behaviors are seasonal for both enlisted populations leading to numerous states being non stationary in part due to their correlation with seasonality. The small percentage of satisfactory states justifies the need to investigate a different metric than the annual monthly transition rate used in this study.

THIS PAGE INTENTIONALLY LEFT BLANK

VI. CONCLUSION AND RECOMMENDATION

A.   CONCLUSION

The purpose of this thesis is to develop a model to forecast the inventory for Marine Corps Reserve NPS and PS enlisted Marines. We build corresponding models with aggregate monthly transition probabilities. That is, the transition probabilities are weighted averages of the monthly transition probabilities for the particular year.

We validate the models, and show that they both fail the stationarity assumption required of Markov Models. We find that approximately 25% of all the monthly transition probability estimates are satisfactorily close to the respective aggregate estimate. In addition, even absurdly low thresholds proportion of satisfactory months yields significantly insufficient number of stationary monthly estimates. We demonstrate that these findings hold for models built from FY09, FY10 and FY11.

B.   RECOMMENDATION

We recommend the construction of a model that incorporates a transition matrix, $P = \{\hat{p}_{ij}\}$ for each individual month. By utilizing monthly transition matrixes, it is reasonable to assume that the rate will be able to identify and tolerate any stationary issues arising during that time period, which would provide the model the ability to deal with seasonality issues that plague the current model due to its use of an annual aggregate transition rate.

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF REFERENCES

Amos, James F. *2011 Report to the House Armed Services Committee on the Posture of the United States Marine Corps*.

Bartholomew, D. J., A. F. Forbes, and S. I. McClean. *Statistical Techniques for Manpower Planning*. Chichester: John Wiley & Sons, 1991.

Bartholomew, D. J. "The Statistical Approach to Manpower Planning." *Journal of the Royal Statistical Society* 20, no. 1 (March 1971): 3–26.

Davis, J. R., T. H. Kimble, and A. U. Hattiangadi. *USMC Reserve Endstrength Model*. Alexandria, VA: Center for Naval Analyses, 2007.

Davis, J. R., T. H. Kimble, and A. U. Hattiangadi. *USMC Reserve Endstrength Model: User's Guide*. Alexandria, VA: Center for Naval Analyses, 2007.

Emery, Nathan N. "Forecasting United States Marine Corps Selected Reserve End Strength." Master's thesis, Naval Postgraduate School, 2010.

Gass, S. I. "Military Manpower Planning Models." *Computers and Operations Research* 18, (1991): 65–73.

Gillard, Richard. "Steps Towards Determining the Right Number of Dental Recruits the Navy Should Access to Meet the Projected Targets for Navy Dental Corps Officers." Master's thesis, Naval Postgraduate School, 2007.

Hattiangadi, Anita, and Ann Parcell with David Gregory, and Ian MacLeod. "SelRes Attrition and the Selected Reserve Incentive Program in the Marine Corps Reserve." CRM D0013618.A2/Final. Alexandria, VA: CNA, 2006.

Hillier, Frederick S., and Gerald J. Lieberman. Introduction to Operations Research. 5th ed. McGraw-Hill, New York, NY, 1990.

Kalamatianou, A. G. "Attainable and Maintainable Structures in Markov Manpower Systems with Pressure in the Grades." *The Journal of the Operational Research Society* 38, no. 2 (February 1987): 183–190.

Lizarraga, Joseph M. "Patterns of Marine Corps Reserve Continuation Behavior: Pre- and Post-9/11." Master's thesis, Naval Postgraduate School, 2011.

Luther, Christopher D. "Post-9/11 Field Grade Officer Requirements in the Marine Corps Reserve." Master's thesis, Naval Postgraduate School, 2011.

"Marine Corps Reserve Administration Management Manual." MCO 1001R.1K. Quantico: VA, U.S. Department of the Navy, 2009.

Nguyen, Van Q. "Analysis of the U.S. Marine Corps' Steady State Markov Model for Forecasting Annual First-Term Enlisted Classification Requirements." Master's thesis, Naval Postgraduate School, 1997.

Price, Jonathon D. "Effects of Activation on Selected Marine Corps Reserve Prior Service Enlisted Continuation Rates in the Post-9/11 Era." Master's thesis, Naval Postgraduate School, 2010.

Raghavendra, B. G. "A Bivariate Model for Markov Manpower Planning Systems." *The Journal of the Operational Research Society* 42, no. 7 (July 1991): 565–570.

Sales, P. "The Validity of the Markov Chain Model for a Class of the Civil Service." *Journal of the Royal Statistical Society* 20, no. 1 (March 1971): 85–110.

Sapp, Jeffrey K. "A Calculator Adaptation of the Markov Chain Model for Manpower Analysis." Master's thesis, Naval Postgraduate School, 1983.

Schumacher, Joseph F. "Forecasting Retention in the United States Marine Corps Reserve." Master's thesis, Naval Postgraduate School, 2005.

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
   Fort Belvoir, Virginia

2. Dudley Knox Library
   Naval Postgraduate School
   Monterey, California

3. Marine Corps Representative
   Naval Postgraduate School
   Monterey, California

4. Director, Training and Education, MCCDC, Code C46
   Quantico, Virginia

5. Director, Marine Corps Research Center, MCCDC, Code C40RC
   Quantico, Virginia

6. Marine Corps Tactical Systems Support Activity (Attn: Operations Officer)
   Camp Pendleton, California

7. Major Chad W. Seagren
   Naval Postgraduate School
   Monterey, California

8. Benjamin J. Roberts
   Naval Postgraduate School
   Monterey, California

9. LtCol Vaughan Pangelinan, Marine Corps Representative
   Naval Postgraduate School
   Monterey, California

10. LtCol Jonathan Price
    Manpower and Reserve Affairs, HQMC
    Quantico, Virginia